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PHYSICO-CHEMICAL AND FUNCTIONAL PROPERTIES OF QUINOA (*CHENOPODIUMQUINOA*)

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ABSTRACT

Quinoa (Chenopodium quinoa) a pseudo cereal, gluten free and amylaceous (starchy), dicotyledonous plant of the Andean region, is widely cultivated in South America, Bolivia and Peru. In India, it is cultivated in Andhra Pradesh, semi-arid Rajasthan and Uttarakhand. The white quinoa grain variety was analyzed for the physical properties like hydration capacity(34%), water absorption capacity(110%), swelling capacity(56%), germination percentage(62%)and grain to flour ratio(1:2).Nutrient content of quinoa grain was found to be protein13.5 g,fat8.85 g, fiber8g, calcium57.3mg, iron10.68mg, and antioxidant activity 14.27 % per 100 gm respectively. The anti-nutritional factor saponin in quinoa grain was found to be 2.8% initially was reduced to 0.18% by sequential washing and soaking of quinoa grain in distilled water. The grains were allowed for germination for 72 hours incubationat 15-25˚C in a dark chamber.

KEYWORDS: White Quinoa Grain, Pseudo Cereal, Rain Fed Crop, Anti-Nutritional Factor, Germination & Functional Properties

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Original Article

INTRODUCTION

Quinoa (*Chenopodium quinoa*) is a plant belonging to the family Amaranthaceae, subfamily Chenopodiaceae and group Thalami florae, order Caryophyllales genus Chenopodium, species quinoa, native to the Andean (community) regions of Chile, Peru, Ecuador and Bolivia. Its cultivation dates back thousands of years (3000–4000 years ago). Being adaptable to different types of soil and climatic conditions, quinoa grain is pseudo cerealand it is considered as stable food in Andean region (Vilcacundo *et al*., 2017). Currently quinoa cultivation occurs successfully in more than 50 countries including France, England, Sweden, Denmark, Holland, Italy, Kenya, India, US, North America, Europe, Australia, and Japan. Quinoa plant attains full maturity at 3 to 7 feet height. The seeds are small, flat and circularwith 1.5mm diameter and 350 quinoa seeds measured about 1g (Galvez *et al*., 2010). It is considered as gluten-free grain, which enables its use in the diet of celiac patients (Ogungbenle *et al*., 2003).

Quinoa grain is an amylaceous, high carbohydrate content, mainly consisting of starch and small percentage of sugars. Its nutritional composition had proteins 12-19g, unsaturated fats 5-10g, dietary fiber 2-8g per 100g of quinoa grain (Carrasco *et al*., 2003), vitamin B 0.2mg-0.4mg, vitamin E comprises to copherols797.2 ppm

and α-tocopherol 721.4 ppm and vitamin C 16.4mgper 100g of quinoa grain. The mineral content of the grains are as follows calcium 70mg, magnesium 161mg, iron 6.3mg, potassium 845mg, phosphorus 355mg, manganese 1.9mg, zinc 1.2mg, copper 10mg and sodium 22mg per 100g of quinoa grain (Galvez *et al*., 2010). Quinoa grain has a large amount of essential amino acidssuch as methionine (9.1 g/100 g proteins) and lysine (7.8 g/100 g protein) when compared to rice and pulses which was lacking in those amino acid. This promotes the awareness about the nutritional importance of quinoa grain (Dini *et al*., 2005).

The Food and Agriculture Organization of the United Nations launched the International Year of Quinoa in 2013 to promote the production, preservation, and consumption of this crop (FAO, 2012). In India, Andhra Pradesh, Uttarakhand and in semi-arid Rajasthan are emerging as the main cultivators of quinoa. It is a rain fed crop mainly grown at winter, between the months of October - March. In 2013, Uttarakhand (Horticulture research) and Andhra Pradesh (Research Institutes) signed an agreement with Peru to grow quinoa in the respective states (Agarwal *et al*., 2013).

The processing of quinoa includes cleaning, dehulling, washing, drying, sorting, grading and packaging. Quinoa may containssome amount of bitter and toxic compounds (i.e., saponin), in the hull. This can be reduced by dehulling and polishing (Nowak *et al*., 2016). Quinoa contains about 1.0% to 1.2% saponin which is bitter and has anti-nutritional effects (Parker *et al*., 2009 and Guevara *et al*., 2013).

MATERIALS AND METHODS

The experiment was conducted at Community Science College and Research Institute, Tamil Nadu Agricultural University, Madurai during 2018-2019. The raw white quinoa grain varieties were procured from Mandsaur, Madhya Pradesh and polished white quinoa grain were procured from Salem.The raw white quinoa grainof 50 g and polished white quinoa grainwere screened to remove the immature grain werewashed and grounded finely. For germination, quinoa grain was washed 3 times with deionized water and soaked for 16 hours, and then it was tied in wet muslin cloth. The grain was keptfor three days at 15-25°C for 72 hours. Then it was dried in a cabinet drier at 60°C for 30 minutes. The germinated grains were grounded finely and stored in airtight container and used for further analysis.

Analytical Grade (AG) Chemicals and reagents were used for the nutritional analysis.

EVALUATION OF GRAINS

Quinoa grain were assessed for physical properties such as thousand grain weight, thousand grain volume, length, breadth, color, bulk density, hydration capacity, swelling capacity, germination ratio, grain to flour ratio. The chemical properties such as protein, fat, fiber, calcium, iron. The functional property (water absorption capacity), antioxidant activity and anti-nutritional factor (saponin) were also analyzed.

THOUSAND GRAIN WEIGHT

Weight of randomly selected thousand grains was recorded in grams using electronic balance with a sensitivity of 0.01mg.

THOUSAND GRAIN VOLUME

Thousand grains randomly selected and dropped in a measuring cylinder containing known volume of distilled water. The difference in volume was recorded in ml.

LENGTH AND BREADTH

The length and breadth of the sample were calculated by the method described by Khan and Ali (1985) using vernier caliber. Ten quinoa grains of uniform size and shape were selected. They were arranged on a graph paper, as it was round in shape it has equal dimension. The distance covered by them was noted by using the vernier caliber.

COLOR

Color measurements (L* a* b* values) of the quinoa grainwas determined using a Hunter chromometer (Model # Lovibond RT 100) with the Lovibond RT Color software (Version 3.0). Before measuring the color of the samples, the instrument was standardized by placing black and white standard plates and L* a* b* color values were recorded. The deviation of the color of the samples to standard were observed and recorded in the computed interface.

The L* values correspond to lightness /darkness and extend from 0 (black) to 100 (white) with higher values corresponding to more lightness. The*a** and *b** values correspond to an object's color dimensions, with *a** values describing a sample's red (+a) to greenness (-a), while *b**values describe a sample's yellow (+b) to blueness (-b). Larger *a** values indicate more redness and larger *b** values indicate more yellowness.

BULK DENSITY

Thirty gram (12-14% moisture content) of the sample was taken in 100 ml measuring cylinder. The cylinder was taped continuously until a constant volume was obtained. The bulk density was calculated as weight of grain (g) divided by grain volume (ml) and it was expressed as g per ml which was reported by Vilche *et al.*, 2003.

HYDRATION CAPACITY

To determine hydration capacity, by using the formula given by (Thathola *et al.,* 2002). The grainnumber weighing 100 g of each were counted and transferred to ameasuring cylinder. To this 100ml distilled water was added andcylinder was covered with aluminum foil and left for 15 hours at room temperature (25±2°C). The grains were drained, superfluous waterwas removed with filter paper and swollen grains werereweighed. Hydration capacity was calculated.

$$\text{Hydrationcapacity}(\%) = \frac{\text{Weight after soaking} - \text{Weight before soaking}}{\text{Weight of seeds}} \times 100$$

SWELLING CAPACITY

To determine swelling capacity by using the formula given by (Thathola *et al.,* 2002). Grain weighing 100gm were counted and transferred to a measuring cylinder and their volume was recorded. To this 100ml water was added and cylinder was covered with aluminumfoil and left for 15 hours at room temperature (25±2°C). The water wasdrained and volume of soaked grains was noted in graduated cylinder.

$$\text{Swelling Capacity}(\%) = \frac{\text{Volume after soaking} - \text{Volume before soaking}}{\text{Weight of grains}} \times 100$$

GERMINATION

100 grains were soaked overnight in water and the water was drained, then it was tied in muslin cloth and incubated at 15 to 25°C for 72 hours. The germinated grains were counted and expressed as percentage (%).

GRAIN TO FLOUR RATIO

100 g quinoa grains were milled and its weight of flour recovered was taken.

PROXIMATE COMPOSITION OF QUINOA GRAIN

The proximate nutrient composition of raw quinoa grain, germinated quinoa grain and polished quinoa grain were estimated by using standard procedure i.e., protein (Ma and Zuazaga 1942), Fat (Cohen 1917), Fiber (Maynard, 1970). The minerals were estimated by calcium (Clark & Colli, 1925), Iron (Wong, 1928).

ESTIMATION OF FUNCTIONAL PROPERTIES

Beuchat's method (1977) was employed for the determination of water absorption capacity. One gram of sample was mixed with 10ml distilled water for 30 sec. the samples were then allowed to stand at room temperature(25±2°C) for 30 min after which they were centrifuged at 3000 rpm for 30 min. the volume of the supernatant was noted in a 10 ml graduated cylinder. Water absorption (mg ml^{-1}) was calculated at the difference between the initial volume of water added to the sample and the volume of the supernatant.

ESTIMATION OF ANTI-NUTRIENT AND ANTIOXIDANT ACTIVITY

The anti-nutrient such as saponin content of raw processed and germinated samples were estimated by the method described in (Obadoni and Ochuko 2002). The radical scavenging activity of the sample was determined by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay quantitative method (Goupy *et al.*,1999)

STATISTICAL ANALYSIS

The data were analyzed using AGRES software, single factor ANOVA analysis with $p \leq 0.05$ was performed to identify significant differences in all experimental parameters carried out in studies at triplicates.

RESULT AND DISCUSSIONS

The nutritional compositions of quinoa grain were superior to other cereals (rice, wheat, corn, millets etc.,) in terms of proteins, lipids and minerals. The physical properties, chemical properties, functional property, antioxidant activity and anti-nutritional property of raw quinoa grain, polished quinoa grain and germinated quinoa grain were assessed.

PHYSICAL PROPERTIES OF QUINOA GRAIN

The physical properties such as thousand grain weight, thousand grain volumes, length, breadth, color, bulk density, hydration capacity, swelling capacity, germination ratio and grain to flour ratio were assessed in the raw, polished and germinated quinoa grain. The experiment details are summarized in Table 1.

THOUSAND GRAIN WEIGHT AND THOUSAND GRAIN VOLUME

The thousand grain weight (3.72g) and volume (2.4 ml) of raw quinoa grain was significantly higher than germinated quinoa grain (3.61g and 2ml, respectively). The corresponding values were lower in polished quinoa grain (3.50g and 1.63ml respectively). Values above 3.0 g per thousand grains are considered as large grains (Spehar *et al.* 2016) and considered more desirable in the growing quinoa market

BULK DENSITY

Bulk density of raw quinoa grain (0.95g/ml) was on par with germinated quinoa grain (0.95 g/ml). But it was significantly lower in polished quinoa grain (0.9 g/ml). Vilche *et al*., 2003 reported that the bulk density of quinoa grain was 1 to 2.5 g/ml.

LENGTH AND BREADTH

The length and breadth of quinoa grain was 0.2 and 0.15 cm respectively in raw, processed and germinated quinoa grain as per the report FAO, 2012.

COLOR

The L* a* and b* value of quinoa grain was 76.1, 2.1 and 24.8 respectively as reported by Valcencia *et al*., 2018.

HYDRATION CAPACITY

The hydration capacity measures the volume occupied by the starch after swelling in excess water, which maintains the integrity of starch in aqueous dispersion. Results showed that significant difference between raw, processed and germinated quinoa grain the hydration capacity was found to be in raw quinoa grain(3.65g/g), germinated quinoa grain(3.6 g/g) and polished quinoa grain (3.4g/g). In general, hydration capacity was decreased after germination. Valencia *et al*., 2009 reported that hydration capacity of quinoa grain was 3 to 4g/g.

SWELLING CAPACITY

Swelling capacity is an important parameters in determining the sample consistency (solid, semi-solid and liquid) and are dependent on the compositional structure of the sample. The swelling capacity of germinated quinoa grainare 56.81, raw quinoa grain 56.32 and polished quinoa grain 56 per cent. The raw quinoa grain, germinated quinoa grain and polished quinoa grain were found to be significant**.** Valencia *et al*., 2009 reported that swelling capacity of quinoa grain was 52 to 63 per cent. The germination per cent was 62 per cent and grain to flour ratio is 1:2 as per the report by Gomez *et al*., 2011.

PROXIMATE COMPOSITION OF QUINOA GRAIN

The chemical composition namely protein, fat, fiber, calcium and iron content of raw, germinated and polished quinoa grain are presented in Table 2.

It was found that the protein content of raw and germinated quinoa grain are on par to each other (15.6 % and 15.69 % respectively). The protein content of polished quinoa grain was significantly lower 13.5 per cent than the raw and germinated quinoa grain. This may be due to increased metabolic activity during hydration of quinoa grain for germination process. Vilcacundo *et al*., 2017 analyzed thesuperiority of protein content (13 to 16.7 %) in quinoa grain.

The fat content of raw, polished and germinated quinoa grain was 8.85 per cent, 8.25 per cent, and 8.2 per cent respectively. Decrease in fat content may be due to depletion of the fat stored that contributed to the catabolic activities of the seeds during sprouting (Onimawo *et al*., 2004).

Fiber content of polished quinoa grain (8 %) was significantly lower than raw quinoa grain (8.5 %) and germinated quinoa grain (8.65 %). This may be due to the removal of the hull during processing (Devi *et al*., 2015). James et al., 2009 reported that total fiber in quinoa grain was about 7 to 11 g/100g.

Calcium and iron content of raw, polished, and germinated quinoa grain were measured. The calcium content was higher in (62.4 mg) followed by raw quinoa grain (61.4 mg) and polished quinoa grain (57.3 mg). The iron content was increased from 10.95 mg (raw quinoa grain) to 11.24 mg (germinated quinoa grain). The iron content of polished quinoa grain was significantly lower (10.68 mg/100g). Ogungbenle *et al*., 2003 reported that quinoa contains calcium 86 mg/100g and Ando et al., 2002 reported that iron contains about 11.5 mg/100g.

FUNCTIONAL PROPERTY AND ANTIOXIDANT ACTIVITY

The functional property (water absorption capacity) of raw, polished and germinated quinoa grain were analyzed. Table 3 illustrates that raw quinoa and germinated quinoa had 121per cent water absorption capacity, however there is slight decrease in polished quinoa grain (110 %). James *et al*., 2009 reported that water absorption capacity was between 93% and 147%.

Antioxidant activity of raw, polished and germinated quinoa grain was measured by DPPH method and the result was denoted in table 3. The antioxidant activity was higher in germinated quinoa seed (16.32 %) and lower in raw quinoa seed (15.63 %). There is slight decrease in polished quinoa seed (14.27 %). Gorinstein *et al*., 2008 showed that quinoa has higher antioxidant activity (25 %)

ANTI-NUTRITIONAL FACTOR

Anti-nutritional factor (saponin) decreased significantly ($p \leq 0.05$) from 2.8 % to 1.2 % during germination of quinoa grain. It was reduced up to 0.15 per cent and in polished quinoa grain up to 0.18 % (Table 4). This may be due to leaching of saponin from the grain during washing and soaking for germination process. Gomez *et al*., 2011 reported that saponin content in quinoa grain was 3.33 %.

CONCLUSIONS

Quinoa is a crop with higher nutrition content such as protein, fats, minerals and amino acid. By creating awareness, this may contribute to worldwide food security. The anti-nutritional factor present in quinoa grain can be decreased by processing and germination. This may results in increased nutritional property of the quinoa grain. On this view, the present study aims to evaluate the functional properties and nutritional benefits of quinoa grain that may increase the awareness of quinoa for consumption as food products.

Table 1: Physical Properties of Quinoa Grain

Physical Properties	Raw Quinoa Grain			Polished Quinoa Grain	Germinated Quinoa Grain
Thousand grain weight (g)	3.72±0.028			3.50±0.015	3.61±0.089
Thousand grain volume (ml)	2.4±0.066			1.63±0.007	2±0.037
Bulk density(g/ml)	0.95±0.151			0.9±0.133	0.95±0.191
Length (cm)	0.2 ± 0.004			0.2± 0.005	0.2± 0.003
Breadth (cm)	0.15 ± 0.002			0.15± 0.003	0.15± 0.001
Color	L* 76.1±1.2	a* 2.1±0.3	b* 24.8± 1.0	-	-
Hydration capacity (%)	36±0.848			34±0.821	36.5±0.889
Swelling capacity (%)	56.32±0.763			56±0.673	56.81±1.238
Germination percentage	62±1.434			-	-
Grain to flour ratio	1:2			1:2	1:2

*Values reported are mean± SD of three replicates.

Table 2: Proximate Composition of Quinoa Grain

Proximate Nutrient	Raw Quinoa Grain	Polished Quinoa Grain	Germinated Quinoa Grain
Protein (g)	15.6±0.074	13.5±0.303	15.69±0.363
Fat (g)	8.85±0.235	8.85±0.283	8.2±0.050
Fiber (g)	8.5±0.063	8±0.223	8.65±0.188
Calcium (mg)	61.4±0.585	57.3±1.481	62.45±1.019
Iron (mg)	10.95±0.156	10.68±0.102	11.24±0.076

*Values reported are mean± SD of three replicates.

Table 3: Functional Properties and Antioxidant Activity of Quinoa Grain

Nutrients	Raw Quinoa Grain	Polished Quinoa Grain	Germinated Quinoa Grain
Water absorption capacity (%)	121±2.531	110±0.299	121±2.529
Antioxidant activity (%)	15.63±0.447	14.27±0.359	16.32±0.511

*Values reported are mean± SD of three replicates.

Table 4: Saponin Content of Quinoa Grain

Quinoa Grain	Saponin Content (%)
Raw quinoa grain	2.8±0.073
Polished quinoa grain	0.18±0.003
Soaked quinoa grain	0.15±0.002
Germinated quinoa grain	0.12±0.000

*Values reported are mean± SD of three replicates

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